ANTI-ROLL LEAF SPRING SUSPENSION

DESCRIPTION

This invention relates to an anti-roll leaf spring suspension of the type comprising a pair of leaf springs, with single or multiple leaves, which extend longitudinally of a vehicle chassis on opposed sides thereof and which are connected to respective ends of anti-roll means, such as an anti-roll bar or tube, extending transversely of the vehicle chassis.

When a vehicle travels over a road surface, the major mass of the vehicle is isolated, by its suspension, from vibrations caused by irregularities of that surface. The loads to which the vehicle suspension is subjected, are borne by the leaf springs of the vehicle suspension.

The softer the vehicle leaf springs, and/or the lower their load deflection rates are, the better the isolation.

The quality of this isolation affects the ride quality of the vehicle and any damage inflicted on the road surface thereby.

There is, however, a limitation on the degree to which the leaf springs can be softened, because the suspensions also have to control the dynamic forces exerted upon them by the mass of the vehicle during changes of direction and/or velocity thereof.

One such direction change occurs when a vehicle changes its direction of travel when being driven around, say, a curve or bend in the road.

During this manoeuvre, the vehicle suspension has to accommodate the centrifugal forces which cause the mass of the vehicle to transfer on to the wheels on the outside of the curve or bend and from the wheels on the inside of the curve or bend.

This mass transfer on to the outside wheels of the vehicle is transmitted to the suspension. The softer the suspension, the more the leaf springs will deflect, thus causing the vehicle to lean or roll.

Owing to the practicalities associated with the design and installation of such a suspension, as well as other dynamic vehicle handling characteristics, there is a limit to the amount and rate of roll which is acceptable. Such a limitation creates a compromise between the ride and handling qualities of the vehicle.

With such a compromise, the amount and rate of roll which is acceptable, limits the softness of the suspension and the associated quality of ride which is available.

To improve or resolve this compromise, additional springs or spring modifications, have been available, which resist vehicle roll, without increasing the

vertical spring stiffness, when both vehicle wheels deflect together.

Such mechanisms are usually known as "anti-roll mechanisms".

However, as the vehicle ride is also dependent upon the vibrations to which the suspension is subjected when only one wheel of the vehicle deflects, there is often a limit as to how much the ride and handling compromise can be extended.

For many years, anti-roll mechanisms have been based upon a separate torsion bar or tube acting transversely of the vehicle between the opposed wheels of the suspension.

A recent development for vehicles which are suspended by leaf springs on each side thereof, have been mechanisms which stiffen the springs internally, only when the springs deflect in opposite directions, as they do when the vehicle rolls.

Leaf springs to which a vehicle chassis is mounted, are effectively pin-jointed beams and set as such. Usually, the leaf springs are fastened to the axle of the wheels in the region of their centres and are mounted to the vehicle chassis via bushes and/or shackles at their respective opposed ends.

The loads applied to the leaf springs create bending moments therein, which, in turn, cause the springs to deflect and, thus, absorb energy.

During vehicle roll, the effective mass of the vehicle is transferred, at the axle, from one spring to the other, changing the bending moments therein. The stiffness of the leaf springs controls the change in deflection of each spring and these now different deflections in each spring, on each side of the vehicle, create, in turn, the amount of roll in the vehicle.

In previous developments of these anti-roll techniques, a torsionally rigid member has been connected between the leaf springs at or adjacent one end of the springs. This member, such as an anti-roll bar or tube, allows the leaf springs to work normally when they deflect together in the same direction, as they normally function when creating the vehicle's primary ride characteristics.

As discussed above, when the vehicle rolls, the leaf springs deflect in different directions as the vehicle mass is transferred to the outside spring from the inside spring. During such deflections, the torsionally rigid member resists the angular differences between the two opposed leaf springs, thereby creating a deflection resisting moment in the springs, which then produces a lower change in bending moment in the springs. This, in effect, changes the

pin-jointed beam nature of the springs into fixed-ended, or encastre, beams.

This lower-than-previous change in bending moment creates smaller spring deflections and thus stiffens the springs during roll only.

Therefore, adding the torsionally stiff member to the ends of the leaf springs, creates an effective anti-roll mechanism.

In practice, this additional bending moment is applied over the physical length of the brackets mounting the torsionally rigid member to the ends of the opposed leaf springs.

Also, it can be seen that this anti-roll mechanism reduces the maximum, and any change in the, bending moment and, therefore, increases the service life of the leaf springs.

In practice also, this mechanism is more effective as an anti-roll mechanism than suggested above. If the torsionally rigid member is added to just one end of the pair of opposed leaf springs, the resultant anti-roll mechanism stiffens just one end of the leaf springs when the vehicle rolls. This creates asymmetrical cantilever deflecting leaf springs, which means that, during vehicle roll, the axle seat area of each leaf spring, which is fastened centrally to the axle, attempts to deflect in different angular directions. Such deflection is resisted by the

torsional rigidity of the axle which, again, tends to stiffen-up the leaf springs. This anti-roll stiffness associated with asymmetrical springs is well known in spring and suspension design practice.

Whilst this anti-roll stiffening of the leaf springs can be very effective, some applications can benefit from even higher and extra spring stiffening for resisting vehicle roll. This could allow the normal ride stiffness to be lowered even further, thus improving the basic vehicle ride and creating an even better compromise between ride quality and anti-roll vehicle handling stability.

To summarise current prior art anti-roll suspension designs, it is normal practise to mount the torsionally rigid member as close as possible to the neutral axis in bending of the leaf springs.

Also, the mountings between the torsionally rigid member and the opposed leaf springs are made sufficiently flexible to allow for the transmission of torque created by the member but to be considered pin-jointed in plan view.

This is achieved by making the brackets mounting the opposed ends of the torsionally rigid member to the ends of the leaf springs, sufficiently narrow or otherwise flexible, to allow the member to move within those mountings.

This is considered to be normal practice to improve assembly, reduce local stresses, create a lightweight structure and avoid interfering with the normal spring deflections.

It is an object of the present invention to provide a leaf spring suspension which provides, during roll of the associated vehicle, further stiffening of the springs beyond that achieved to date, as discussed above, to improve the anti-roll characteristic of the suspension and, as a consequence, its performance and durability.

Accordingly, the invention provides a suspension for a vehicle, comprising a pair of leaf springs located or locatable on respective opposed sides of a vehicle chassis and extending longitudinally thereof, and an anti-roll device which is arranged to extend transversely of the vehicle chassis, and means mounting opposed ends of the anti-roll device rigidly to respective ones of the pair of opposed leaf springs.

Preferably, the mounting means is arranged to clamp the opposed ends of the anti-roll device rigidly to respective ones of the pair of opposed leaf springs.

This rigid clamping or other form of mounting effectively renders the mounted end of the anti-roll device fixed or so-called "encastre" in bending, when viewed in plan, thereby exploiting the anti-roll

device's bending stiffness to create higher anti-roll stiffening of the leaf springs.

The anti-roll device may have its opposed ends mounted rigidly by the mounting means to any position along the lengths of the pair of opposed leaf springs, although at least one end of those leaf springs is preferred.

The rigidity of the mounting of the anti-roll device to the leaf springs, as provided by the clamping or other mounting means, creates a higher resistance force to bending of the anti-roll device, in plan view, which occurs when the leaf springs deflect in opposite directions during, say, vehicle roll. This higher-than-previous resistance force creates a bending moment in the leaf springs when it acts offset from the neutral axis in bending of the springs, which resists the change in bending reducing, in turn, leaf spring deflection during vehicle roll. Thus, the extra bending rigidity stiffens the springs during vehicle roll and creates this extra anti-roll resistance within the suspension.

The opposed ends of the anti-roll device may be offset from the neutral plane in bending of each of the opposed leaf springs by means of spacers.

In a preferred embodiment to be described hereinbelow, the mounting means provides a comparatively large clamping area, which has

previously been comparatively small, between the mounting means and the anti-roll device.

The anti-roll device itself may be of any suitable form, for instance, a beam, bar or tube.

In order that the invention may be more fully understood, embodiments of suspension in accordance therewith will now be described by way of example and comparison with existing prior art suspensions, with reference to the accompanying drawings in which:

Figure 1 is a perspective, generally diagrammatic view of a prior art leaf spring suspension without an associated anti-roll device;

Figure 2 is a diagrammatic side elevation of the springs of the suspension shown in Figure 1;

Figure 3 is a simplistic bending moment diagram for the springs of the suspension shown in Figures 1 and 2;

Figure 4 is a simplistic bending moment diagram for the suspension springs shown in Figures 1 and 2, under vehicle roll conditions;

Figure 5 is a perspective diagrammatic view of a prior art suspension fitted with an anti-roll device;

Figure 6 is a simplistic bending moment diagram for the springs of the suspension shown in Figure 5 under vehicle roll conditions;

Figure 7 is a diagrammatic side view of a suspension in accordance with the invention, in its steady state condition;

Figure 8 is a side view of the suspension shown in Figure 7, with its leaf springs in respective rebound and compression configurations;

Figure 9 is a plan view of the leaf spring suspension shown in Figure 8, with the springs in their respective rebound and compression configurations;

Figure 10 is a simplistic bending moment diagram for the first embodiment of leaf spring suspension shown in Figures 7 to 9; and

Figures 11 to 13 are respective plan, end and side views of a detail of the leaf spring suspension shown in Figures 7 to 9, showing a preferred form of mounting means therefor.

For a better understanding of the improved anti-roll capabilities of a suspension in accordance with the invention, two known prior art leaf spring suspensions will be discussed initially.

As indicated above, leaf springs on vehicles act effectively as pin-jointed beams and are usually mounted to the vehicle axle at or adjacent their centres and to the vehicle chassis via bushes and/or shackles at their respective opposed ends.

Such a prior art suspension is shown in Figure 1, wherein a pair of generally parallel leaf springs 1 are mounted, at their centres, to respective opposed end regions of an axle 2.

The leaf springs 1 extend longitudinally of the chassis 3 of the associated vehicle (not shown) and the axle has a pair of running wheels 4 at respective opposed ends thereof.

The fore and aft ends of each leaf spring 1 are mounted to the vehicle chassis 3 by respective brackets 5, 6 and associated bushes 7 and shackles 8 in known manner.

Effectively, the fore and aft ends of each leaf spring 1 are pin-jointed at 9 and the lower bush 10^{1} of the shackle 8, the upper bush 10 of each shackle 8 being shown in Figure 1, so that the fore and aft cantilever sections of each leaf spring 1 in effect act as pin-jointed beams.

The loads L applied to the leaf springs 1, as shown in Figure 2, create a bending moment in each leaf spring 1, as shown in the bending moment diagram 11 of Figure 3.

Such bending moment causes each leaf spring 1 to deflect, thereby absorbing energy during normal working of the suspension when the leaf springs 1 deflect together.

During vehicle roll, however, the mass of the vehicle is transferred, at the axle 2, from one spring 1 to the other, creating bending moments, as shown by the respective bending moment diagrams 12, 13 of Figure 4.

The stiffness of the leaf springs 1 controls the change in deflection of each spring 1 and these now different deflections in the springs 1, on each side of the associated vehicle, create, in turn, the amount of roll to which the vehicle is subjected.

Thus, in Figure 4, as in Figure 3, the steady state, bending moment diagram is represented at 11, whilst the unrestricted compression, bending moment diagram for the leaf spring 1 on the outside of a curve or bend being negotiated by the vehicle, is indicated at 12.

The unrestricted rebound, bending moment diagram for the leaf spring on the inside of the bend or curve being negotiated by the vehicle, is shown at 13.

In the development of prior art, anti-roll systems, a torsionally rigid member, such as an anti-roll bar or tube, is mounted transversely of the

vehicle chassis 3, with its opposed ends mounted at or adjacent the fore and aft ends of the leaf springs 1.

Such an anti-roll suspension arrangement is shown in Figure 5, with the torsionally rigid member indicated at 12.

This member 12, usually in the form of a beam, bar of tube, permits the leaf springs 1 of the suspension to work normally when they deflect together in the same direction, as they function normally when creating the vehicle's primary ride characteristics.

When, however, the vehicle rolls, for example, when negotiating a bend or curve, the leaf springs 1 deflect in different directions, as the mass of the vehicle is transferred to the outside leaf spring. During these deflections, the torsionally rigid member 12 resists the angular differences between the two leaf springs 1, creating a deflection resisting moment in the springs 1, which then produces a lower change in bending moment in the springs 1.

This, in effect, changes the pin-jointed beams, represented by the leaf springs 1, into fixed-end, or encastre, beams.

This change in bending moments is illustrated in Figure 6 in which the steady state bending moment diagram is again shown at 11, the unrestricted compression bending moment diagram, at 12 and the unrestricted rebound bending moment diagram, at 13.

The revised compression bending moment diagram resulting from the resisting moment b provided by the torsionally rigid member 12 of the suspension, shown in Figure 5 is represented at 14, whilst the revised rebound bending moment diagram, again resulting from the resisting moment b provided by the torsionally rigid member 12, is shown at 15.

These lower changes in bending moments, as represented by the bending moment diagrams 14 and 15 in Figure 6, create smaller-than-previous spring deflections and, thus, stiffen the leaf springs 1 during roll only.

Thus, adding the torsionally stiff member 12 to the leaf springs 1 of the suspension, creates an effective anti-roll mechanism.

For simplicity, the bending moment diagrams of Figure 6 show the added deflection resisting moment, as if it were applied directly to the ends of the leaf springs 1. In practice, this additional moment would be applied over the physical length of the means, such as brackets, used to mount the torsionally rigid member 12 to the springs 1.

Also, it can be seen that the anti-roll device reduces the maximum, as well as change, in bending moment and, therefore, increases the service life of the springs 1.

In practice, this device is more effective as an anti-roll mechanism than suggested above.

If the torsionally rigid member 12 is mounted to just one cantilever, for example, the fore cantilever, of each leaf spring 1, as shown in Figure 5, the effective anti-roll mechanism stiffens only one cantilever, or end, of each spring 1 when the associated vehicle undergoes roll. This creates asymmetrical cantilever deflecting springs which means that during vehicle roll, the seat area of the axle 2, which is mounted centrally of each leaf spring 1, attempts to deflect in different angular directions, this being resisted by the inherent torsional rigidity of the axle 2, again stiffening the springs 1.

This anti-roll stiffness of asymmetrical leaf springs is well known in spring and suspension design practice.

Whilst this prior art anti-roll mechanism can be effective, some applications can benefit from even higher, extra spring stiffening to resist vehicle roll. Such would allow the normal ride stiffness to be lowered even further, thus improving the basic ride when the springs 1 move together in the same direction. Such additional stiffness would create an even better compromise between ride quality and anti-roll handling stability and other characteristics.

Accordingly, the invention provides a leaf spring suspension which creates this better resistance to

vehicle roll, such a suspension being shown diagrammatically in Figures 7 to 9.

As discussed above, it is normal practice with current, prior art leaf spring suspensions having an anti-roll mechanism associated therewith, to mount the torsionally rigid member 12 as close as possible to the neutral axis in bending of the leaf springs 1. Also, those mountings are made sufficiently flexible to allow for the transmission of torque created by the torsionally rigid member 12 but to be considered as pin-jointed in plan view. This is achieved by making the brackets or other mountings for mounting the torsionally rigid member 12 to the opposed leaf springs 1 sufficiently narrow and/or flexible, to allow the member 12 to move within its mountings. This normal suspension practice improves assembly, reduces local stresses, creates a lightweight structure and avoids interfering with the normal spring deflections.

The invention, however, provides a suspension which exploits the bending stiffness of the torsionally rigid member 12 to create higher anti-roll spring stiffening, wherein the member 12 is mounted offset from the neutral axis in bending of the leaf springs and, also, is mounted rigidly thereto. This rigid mounting effectively renders the ends of the torsionally rigid member 12 fixed, or encastre, in bending, when viewed in plan, as shown in Figure 9.

This added rigidity creates a higher resistance force to the bending of the member 12 in a generally horizontal plane, which occurs when the leaf springs 1 deflect in opposite directions, during vehicle roll. This higher-than-previous resistance force, when it acts offset from the neutral axis in bending of the leaf springs 1, creates a bending moment in the springs, which resists the change in bending which, in turn, reduces deflection of the springs 1 during vehicle roll. Thus, extra bending rigidity stiffens the springs 1 during vehicle roll and creates this extra anti-roll function within the suspension.

This can be more readily explained when discussed in conjunction with Figures 7 to 10 of the drawings.

Thus, Figure 7 is a diagrammatic side view of the suspension in accordance with the invention, with the leaf springs 1 inverted and only their neutral axes in bending shown, in order to simplify the discussion.

To all intents and purposes, a basic leaf spring is considered to be a regularly-sectioned beam which deflects under a bending load to create a tension stress in the upper surface of the beam and a compression stress in the lower surface of the beam, the neutral axis in bending of the leaf spring being that internal layer of the beam which extends longitudinally and approximately centrally of the section of the beam, which undergoes zero (neutral) bending stress and about which the beam (leaf spring)

deflects (bends) to absorb the energy caused by such deflection (bending).

Thus, in Figures 7 and 8, the neutral axis in bending of the leaf springs is indicated at 21, when the springs are in their steady state.

Also as shown in Figures 7 and 8, the opposed ends of the transversely-extending torsionally rigid member 12, shown in Figure 9, are indicated at 22 and 23.

Also, the longitudinal axis of the torsionally rigid member 12 is offset by a distance <u>x</u> from the neutral axis in bending 21 of each leaf spring 1.

In accordance with the invention, the torsionally rigid member 12 has its respective opposed ends mounted rigidly to the corresponding ends of the pair of leaf springs 1, so that there is no movement therebetween, however small, during use of the suspension, particularly during vehicle roll.

In Figure 8, the upper neutral axis in bending 21^{I} is that of one of the leaf springs 1 in its rebound configuration, whilst the lower neutral axis in bending 21^{II} is that of the other leaf spring 1 in its compression configuration, during roll of the vehicle.

The corresponding positions of the ends 22, 23 of the torsionally rigid member 12 are also shown in Figure 8.

Thus, one leaf spring, on the outside of a curve or bend being negotiated by the vehicle, deflects further than the steady state, whilst the other spring, on the inside of the curve or bend, deflects less than its steady state, resulting in fore and aft movement of respective ones of the ends 22, 23 of the torsionally rigid member 12, as shown in Figure 9.

In that Figure, the view is in plan in the direction of the arrow A in Figures 7 and 8, with the movements of the opposed ends 22, 23 of the member 12 mounted rigidly to the leaf springs 1, being evident.

The torsionally rigid member 12 can be seen to be stressed, as if it were a beam with fixed ends and with those ends moving apart, as if one was a "sinking end", as defined in applied mechanics.

This creates forces at the ends 22, 23, as shown at F in both Figures 8 and 9. These forces F act at a distance <u>x</u> from the neutral axes in bending 21^{I}, 21^{II}, of the respective leaf springs 1, thus creating moments Fx around those neutral axes in bending.

Figure 10 is a bending moment diagram similar to that shown in Figure 6 but with those additional bending moments added. It can be seen that those moments Fx reduce further the change in bending moment during the load changes created by vehicle roll whilst the vehicle is manoeuvring a bend or curve.

In Figure 10, the steady state bending moment diagram is again indicated at 11, whilst the unrestricted compression and rebound bending moment diagrams for the prior art suspension without an anti-roll mechanism, as shown in Figure 1, are indicated at 12 and 13 and with an anti-roll mechanism, as shown in Figure 5, at 14 and 15.

The improved bending moment diagrams, as reduced compression and rebound bending moment diagrams, are indicated at 31 and 32.

Thus, this lower, bending moment change generated by the inventive suspension creates lower spring deflection, thus stiffening the springs 1 and reducing roll.

Referring now to Figures 11 to 13 of the drawings, here is shown a mounting arrangement between one end of the torsionally rigid member 12 and the fore end of one of the leaf springs 1.

This mounting arrangement comprises an upper, flanged, U-shaped clamp 41 and a lower, generally planar clamp 42.

The torsionally rigid member 12 which is in the form of an anti-roll tube, shown in square cross-section in Figures 11 to 13, is located within the channel defined by the upper clamp 41, as shown clearly in Figure 13.

Between the lower clamp 42 and the flanges 43 of the upper clamp 41 and the anti-roll tube 12, there is provided a spacer block 44 whose lower surface is channelled at 45 to nest with the upper surface of the leaf spring 1.

The arrangement is held together by a pair of U-bolts 46 which embrace the lower clamp 42 and whose upper, otherwise free ends, extend through corresponding holes in the flanges 43 of the upper clamp 41, with securing nuts 47 being provided.

The neutral axis 21 in bending of the leaf spring 1 is shown in dashed lines in Figure 13.

The mounting arrangement is clamped so tightly together by means of the U-bolts 46 and securing nuts 47 that there is no relative movement whatsoever between the anti-roll tube 12 and leaf spring 1 within that arrangement during use of the suspension under normal and roll conditions.

In this manner, and as discussed above, such an arrangement provides additional stiffening for the leaf spring 1, thus reducing roll during cornering, for example, around a bend or curve, by the associated vehicle.

This is in distinct contrast to the prior art anti-roll suspensions, wherein the mounting arrangements for the anti-roll mechanism and associated leaf springs are structured, to allow at

least slight movement therebetween, particularly during vehicle roll.

Additionally, the anti-roll tube 12 is offset considerably from the neutral axis 48 in bending of the leaf spring 1, which contributes to stiffening of the spring 1 during vehicle roll.

Although a spacer 44 is provided in this particular embodiment, such a component may be omitted, as long as the anti-roll tube is offset sufficiently from the neutral axis 48 in bending of the leaf spring 1, to provide, in combination with the rigidly-clamped mounting arrangement, the additional stiffening of the spring 1 during vehicle roll.

Further, and in order to enhance the rigidity of the mounting arrangement, the clamping areas provided by the upper and lower clamps 41, 42 are comparatively large when compared against the clamping areas of prior art arrangements which, as mentioned above, are usually narrow.

Thus, in this particular embodiment of inventive leaf spring suspension, the clamping area is both comparatively wide and long to provide the greatest possible area.

All the suspensions discussed above in both the prior art and inventive arrangements show the additional member 12 at one end of the springs. This

arrangement can also be applied to both ends of the springs, if required.